Hydrostatic and Nonhydrostatic Nested Modeling of Straits in the Philippines Archipelago

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LONG-TERM GOALS

This study utilizes nested nonhydrostatic models embedded in hydrostatic models to simulate and predict the submesoscale dynamics of straits at high spatial and temporal resolutions. The goal of this work is to understand the submesoscale dynamics of straits and the impact of these dynamics on the throughflow in the straits. The Navy requires the ability to forecast features and circulations forced by these dynamics on scales that impact naval operations, kilometers to meters.

OBJECTIVES

The primary objective is to understand the submesoscale dynamics in straits using nested nonhydrostatic models embedded in hydrostatic models. Specifically we will work

- To understand the effects and interactions of the primary forcing components:
  - Tides, especially the spring-neap tidal cycle and remotely versus locally generated tides,
  - Large scale circulation, particularly the Pacific to Indian ocean throughflow and it's seasonal variability,
  - Winds, especially the Southeast Asian monsoon cycle,
- To establish the resolution (dx and dz) and the aspect ratio (dx/dz) required to accurately simulate submesoscale physics and structures,
- To determine the importance of accurate and detailed representation of topography and forcing, especially at open boundaries,
- To understand the impact of rotation on the flow in straits, this is particularly important to nonhydrostatic physics,
- To explore the impact of data assimilation in a nonhydrostatic model, especially for sparse and irregular data,
- To compare model and field observations both for planning and for assessment.

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APPROACH

We use a system of multiply nested nonhydrostatic model (NRL-MIT) domains which utilize hydrostatic models (NCOM and/or HYCOM) to provide open boundary conditions for the coarsest NRL-MIT domain. The NRL-MIT domains consist of the nonhydrostatic version of the MITgcm model wrapped in a suite of scripts that provide initial/restart fields, open boundary values and handle output in a series of segmented, parallel integrations that maximize cpu usage and the ratio of system to wall clock time. The forcing consists of surface fluxes from the NOGAPS and COAMPS operational nowcast/forecast systems and open boundary conditions from the NCOM and/or HYCOM nowcast/forecast systems. HYCOM forecasts with resolutions of up to 4 km may be available in the region in the next year or two (Harley Hurlburt, personal communication). The basic bathymetry will be the NRL DBDB2 (2 minute) bathymetry which we hope will be enhanced and improved with several additional bathymetry databases obtained during the DRI.

WORK COMPLETED

A NRL-MIT model domain has been defined for the Apo Reef – Panay Sill (ARPS200) region (Figure 1). The domain is a rotated spherical polar grid rotated -44° from east to coincide with the orientation of the Mindoro Straits. The domain is 300 km (along the strait) by 150 km (across the strati) with a nominal resolution of 1/200° or 500 m. The vertical grid is variable with a minimum dz of 10 m, a maximum dz of 81 m and a maximum depth of 1882 m. The model time step was 10 s.

This domain was particularly challenging due to the rotated grid and the extensive islands and the complex bathymetry. We also had to implement a Flather boundary condition and an a priori volume conservation scheme to prevent the solution from diverging due to small inconsistencies in the lateral fluxes.

We acquired NCOM data (Figure 2) from NRL/MTRY’s 3 km forecast of January and February 2008. We hindcast the IOP period of 2/12/2008 – 2/27/2008. The domain contains 600 points along the strait and 300 points across the strait with 74 points in the vertical for a total of 13.3 million grid points. The hindcast used 144 processor elements and 330,0000 processor hours in 6 days of wall clock time.

RESULTS

In this region salinity is a better tracer than temperature. The salinity at 50 m (Figure 3, upper panel) shows filaments and submesoscale vortices forming around islands, ridges and seamounts. Internal waves forming at southern boundary and along Mindoro coast. This picture is consistent with satellite and in situ observations.

The salinity at 250 m (Figure 3, lower panel) has more vortical structure and vortex streets behind obstacles. The flow is more confined by the bathymetry. Both depths indicate that the viscosities chosen for this initial hindcast are too large. This is being corrected.

The hindcast has a three layer flow structure as seen in observations (Arnold Gordon, personal communication). The upper layer (50 m) flow is toward the northwest while the lower layer (250 m) flow is toward the southeast and the intermediate layer flow is mixed (Figure 4).

IMPACT/APPLICATIONS

Tactical scale or submesoscale forecasting in domains of 100 to 200 km will require nonhydrostatic modeling systems with resolutions of 100s of meters or less to correctly predict the NLIWs, turbulent regions, fronts, boils and small scale eddies. This project studies the dynamics of NLIWs, their interactions and their impact on the tactical environment. This work furthers the basic understanding of NLIWs and lays the foundation for fututre nonhydrostatic forecast systems.

RELATED PROJECTS

This project is synergistic with the following projects:

NonLinear Internal Wave Initiative (NLIWI) ONR DRI,

Effects of Non-Acoustic Noise on Multi-Sensor USW Networks, NRL 6.2 core

Horizontal Array-Gain Variability due to Transverse Shelf-break Dynamics, NRL 6.2 core

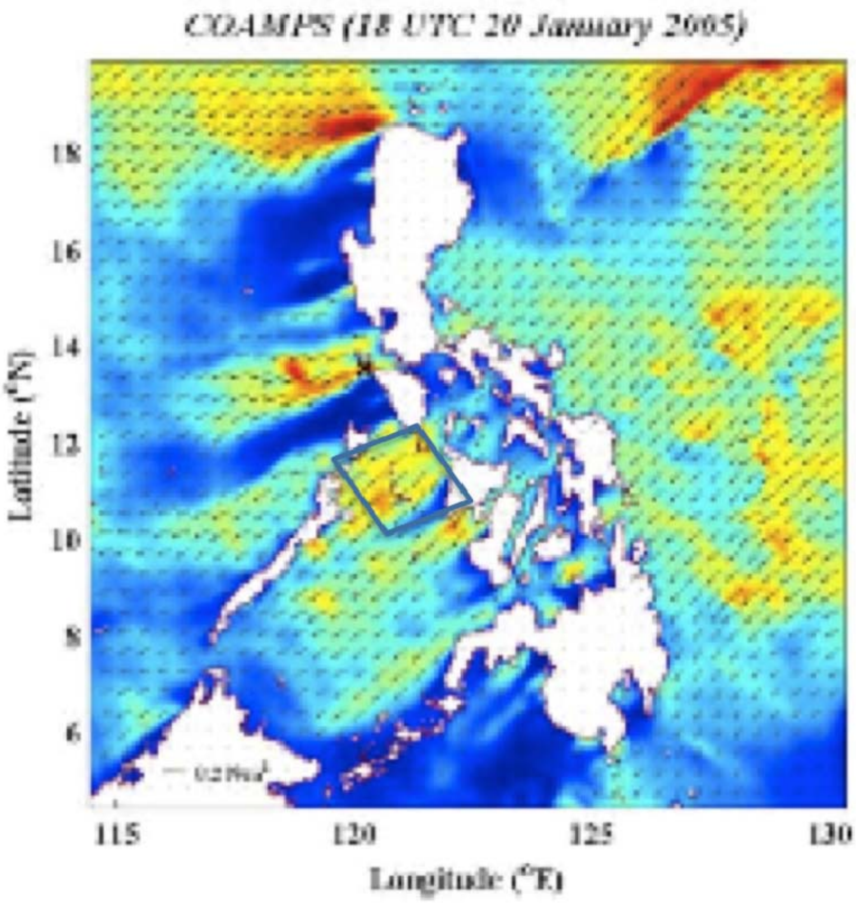

Figure 1. COAMPS domain with NRL-MIT model shown in the blue box.

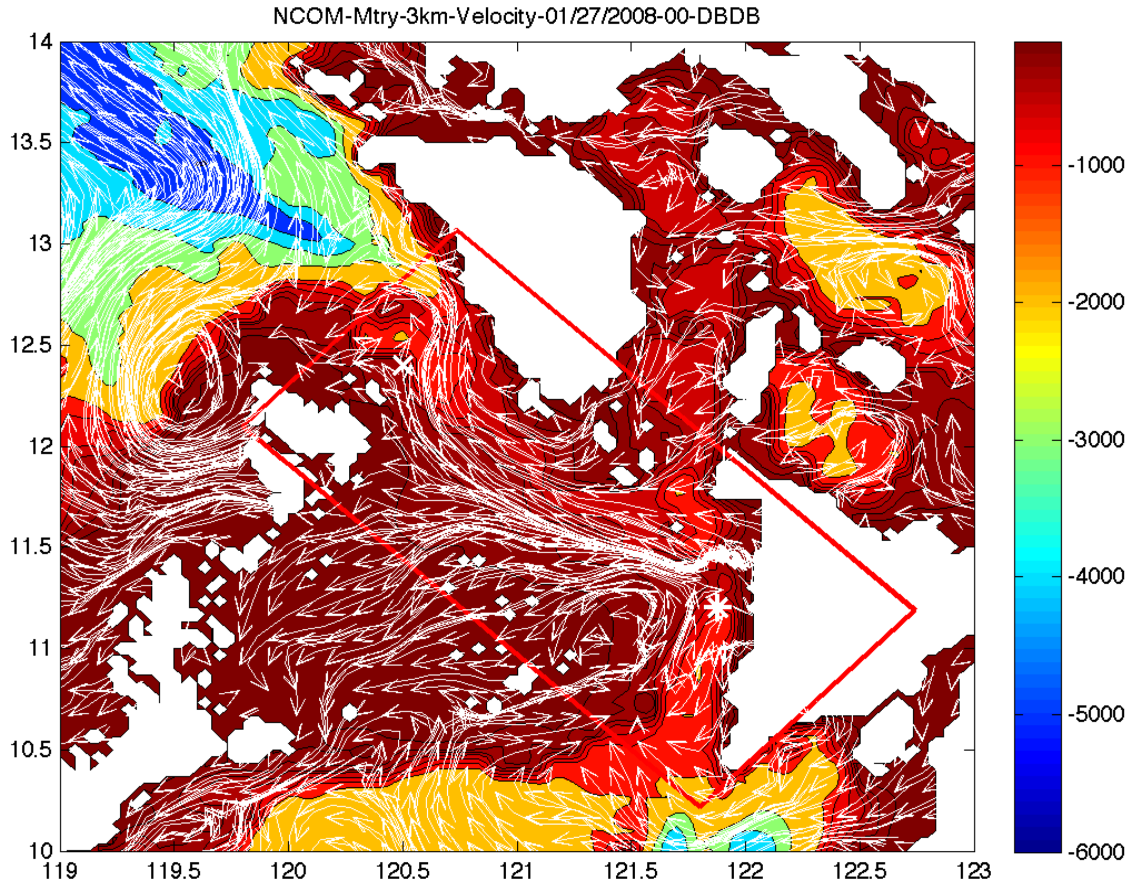

Figure 2. Surface velocity from the relocatable NCOM/COAMPS model for 0000Z January 27, 2008. Color contours are depth. The MIT domain is overlayed in red.

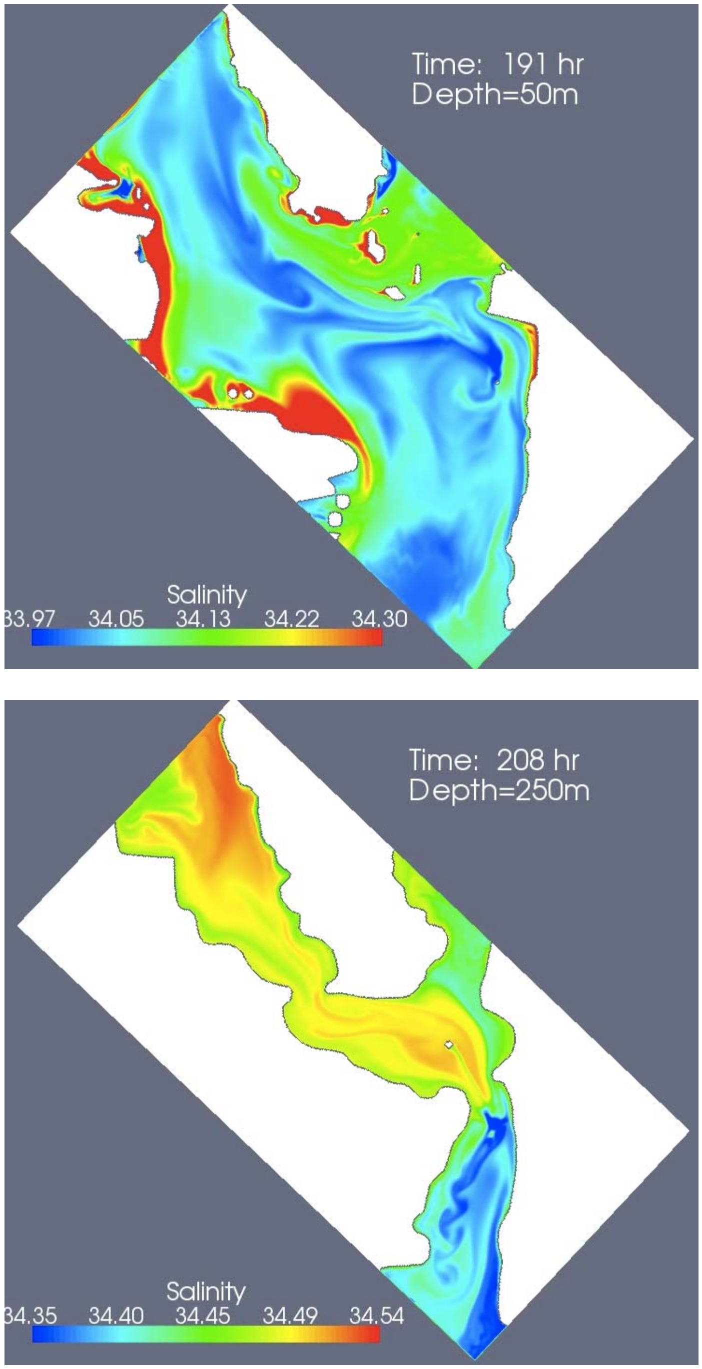

Figure 3 shows a structure more constrained by bathymetry and more vortical. The upper layer salinity shows filament and island wakes and internal waves. The 250 m depth is more constrained by topography and is more vortical.

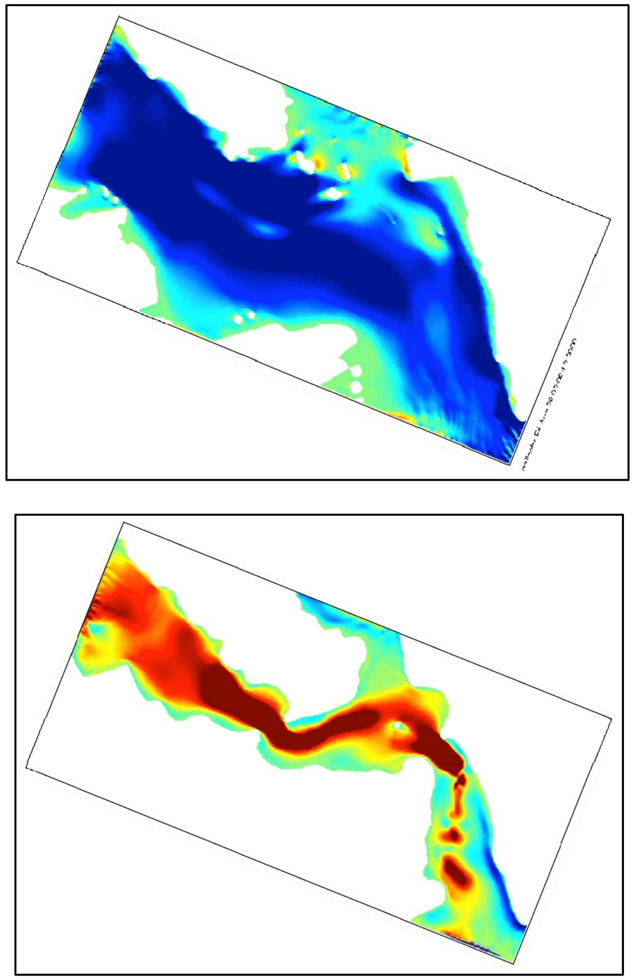

Figure 4. The upper panel is the along strait velocity (contour range is -0.25 m/s to 0.25 m/s). The lower panel is the along strait velocity at 250 m (contour range is -0.15 m/s to 0.15 m/s).